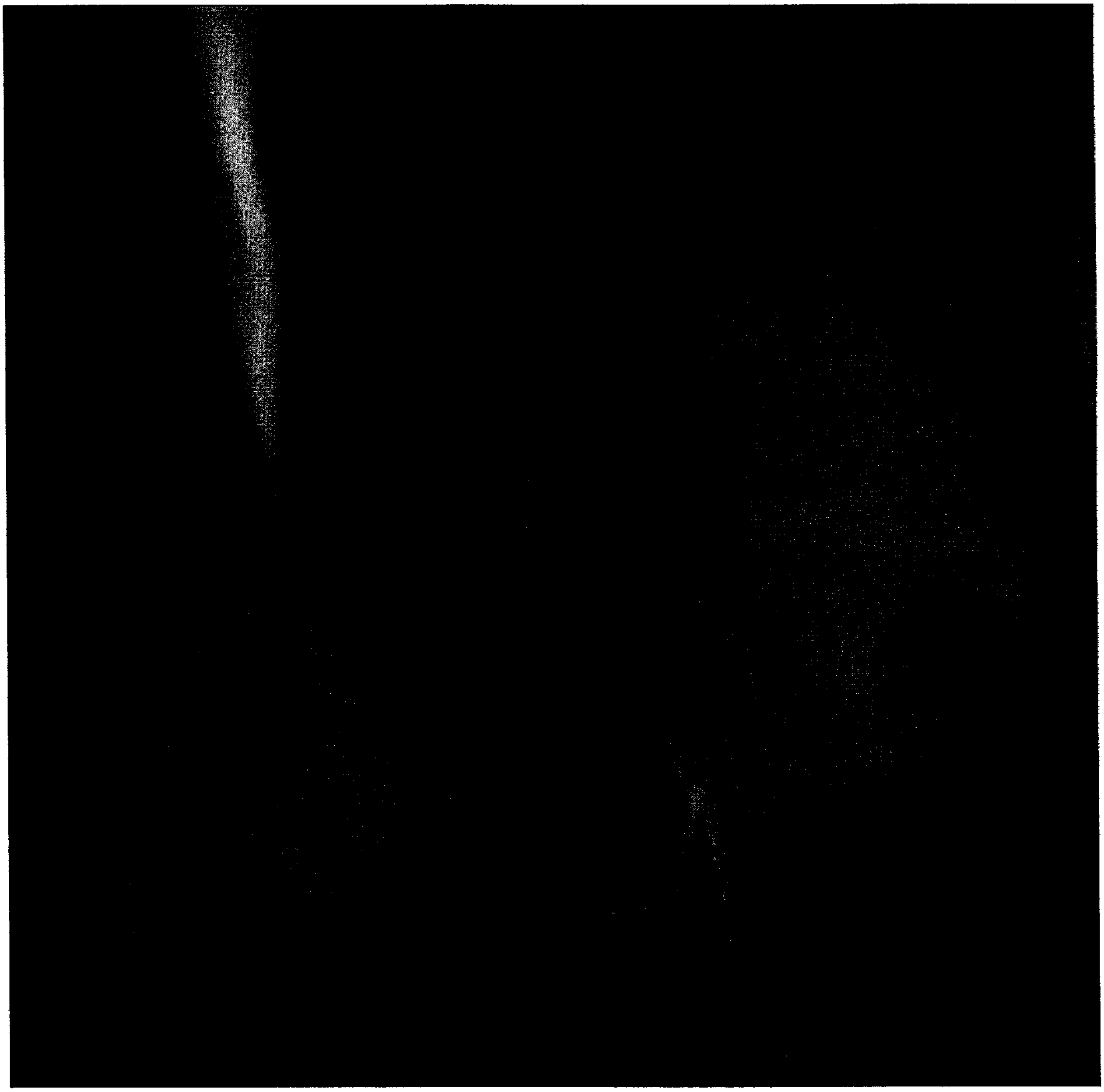
The Northern Lights of Our Sky



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Introduction

The northern lights, or aurora borealis, have been a part of our heritage for as long as the snow has been part of our lives and perhaps even longer. Aurora are visible throughout the world, but are most spectacular during the clear, cold, dark nights of winter that grip the poles. Many believe nature's light show surpasses any modern fireworks display. As the curtain of beauty engulfs the horizon, one can only be awestruck by the beauty of this natural phenomenon.

The aurora are essentially lights high in our sky that work like neon lights. Different names are given to the aurora depending on where they are seen. For instance, aurora of the northern hemisphere are called aurora borealis, aurora of the southern hemisphere are called aurora australis, and aurora polaris is a general term for aurora regardless of their location. It is believed the term 'aurora' was coined in 1619 by Galileo Galilei, the famous mathematician, physicist, and astronomer. In Roman mythology, Aurora was the name given to the Goddess of the Dawn.

The beauty and complexity of the aurora lead to many questions. What is the aurora and why does the aurora occur? What stories and legends do different peoples have concerning the aurora? Do other planets have aurora? And how can I capture the aurora on film? The purpose of this report is to answer these frequently asked questions, and to explain the mystery behind the many different shapes and colours of the aurora.

Folklore and history

Volumes could be written concerning the history and legends surrounding the occurrence and meaning of the aurora. People from across the Canadian north, Alaska, Greenland and Scandinavia have legends and tales that explain the meaning of the aurora, and describe how its shape, colour and sound changes. To many people, the aurora represents the spirits of those who have died and who are in the afterlife. The indigenous people of eastern Greenland believed that the northern lights were the spirits of children who had died at birth. Those from Labrador felt that the lights were really torches held by spirits who were seeking to help the souls of the recently departed find their way. People from the lower Yukon River believed the aurora were the dancing spirits of animals.

References to the aurora are also found in the Old Testament. For example, in 2 Maccabees the author makes reference to 'horsemen charging in midair.' Scientists believe this is a description of the aurora. Much later, during the time of the Roman Empire, a Roman philosopher, named Seneca, wrote a paper entitled *Quaestiones Naturales*. This is believed to be one of the first 'scientific descriptions' of the aurora. This was followed by the paper, *Meteorologica*, written by Aristotle. Many well known scientists attempted to explain the aurora, including Galileo Galilei, Tycho Brahe, Rene Descartes, Edmund Halley and Benjamin Franklin. In *Aurora, the Mysterious Northern Lights*, Candace Savage provides an interesting description of the scientific breakthroughs and dead ends that were encountered in the study of the aurora.

Although the aurora was often viewed as an object of hope, or as the pleasures of the afterlife, this was not the only view, especially for those living in the mid-latitude regions of the globe. In these areas the aurora may be blood red in colour, so people connected the aurora with battle and bloodshed. In Italy and France, for example, the aurora was a sign of coming danger, and it struck fear in the hearts and minds of the local people.

What causes the aurora?

To understand how the aurora are produced requires an understanding of three main components:

- the solar wind,
- the magnetosphere, and
- the earth's atmosphere.

The solar wind is the first factor that must be understood. Because the sun is so hot, it is mainly made up of charged particles – electrons and protons – which are the basic parts of matter. The sun continuously gives off these particles in a fast stream called the solar wind. The particles reach supersonic speeds of several hundred kilometres per second in the solar corona as they rush away into deep space. The earth and its surrounding magnetic force field (the magnetosphere) are in the path of the solar wind, and the force of the wind distorts our protective magnetic field as shown in Figure 1.

The magnetosphere surrounding the earth occupies a volume of space tens of thousands of times larger than earth itself. The earth's magnetic field originates deep inside the planet with the resulting magnetic field looking very much like that of a bar magnet with a north pole and a south pole. The magnetic field is distorted by the solar wind so that it is compressed like a comet's

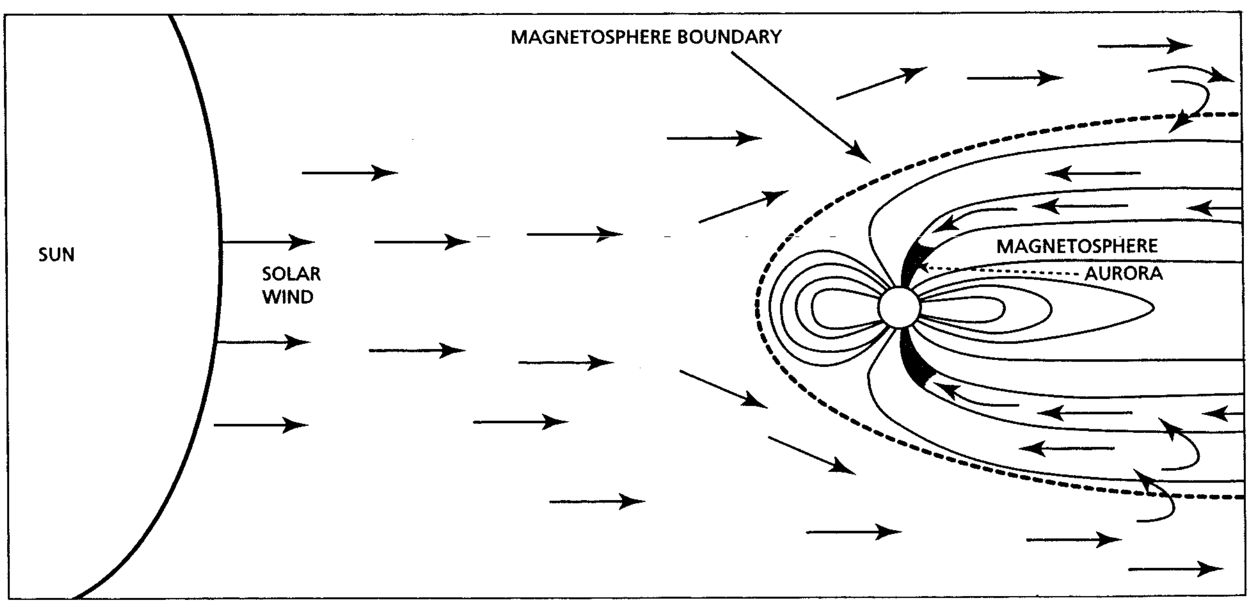

Figure 1.The solar wind strikes and distorts the earth's magnetosphere. Some particles within the solar wind travel along the magnetosphere before turning back towards earth, and eventually colliding with oxygen and nitrogen in the atmosphere to produce the aurora. (Figure from Davis 1992).

head on the side facing the sun (day-side), and a long tail stretching away from the sun on the night side.

Magnetic fields can deflect charged particles, and the earth's magnetic field stops most of the solar wind particles from entering the earth's atmosphere and coming close to the earth. Some particles, however, leak across the boundary of the magnetosphere and they carry with them the energy of motion which ultimately powers the aurora.

Protons are very massive compared to the electrons and, consequently, they carry the energy in the solar wind. From the time the solar wind particles leak into the magnetosphere, energy begins to be transferred by electric currents (wave particle interactions) from the protons to the electrons. It is the energized electrons which are directly responsible for the creation of the auroras. The electrons and protons that have entered the magnetosphere first blow down the long tail of the magnetosphere. Eventually, they turn around and come back toward the earth on the night-side guided by the magnetic field lines (Figure 1). To better understand the movement of the electrons one just has to think of the air movement in a moving convertible. The air rushes by from the front to the back, but the draft in the convertible is from back to front. This type of particle motion is called convection, and describes both the air rushing forward in the convertible and the movement of charged particles in the magnetosphere. The charged particles begin to collide with atmospheric particles of oxygen and nitrogen somewhere between 90 and 250 km above the earth. The collisions between these particles produces the auroras as we shall now describe.

In the earth's atmosphere, immediately above 100 km, most of the particles are atomic oxygen. Although people breathe molecular oxygen, which is comprised of two oxygen atoms bound together, solar radiation breaks oxygen molecules apart. Consequently there is very little molecular oxygen above 100 km in altitude. Any atom can exist in many possible energy states. Some energy states are very short lived, and an atom can exist in that state only for a short time before it gives up some energy and drops to a lower energy state. The energy given off is sometimes visible light with the colour being determined by the change made by the atom or molecule from the higher energy state to the lower energy state. In the case of the auroras, energetic electrons that penetrate as close as 200 to 300 km above the earth begin to collide with the atmospheric particles and excite them.

Two commonly excited states of atomic oxygen lead to green and red light being emitted when the excited atoms drop down to lower energy states. Since the human eye is more sensitive to green light than to red, most people say that the most common auroral colour is green. As well, it turns out that red light is only produced at altitudes above about 200 km where there are few atoms to radiate when they are excited. In contrast, green light can be produced down near the 100 km level where there is a great deal of atomic oxygen available to be excited and to radiate. One final colour seen in the aurora is a reddish purple which is sometimes seen at the lower border of auroral forms. This light is produced by the radiation of molecular nitrogen after it has been excited by the most energetic or primary electrons which can penetrate to within less than 100 km of the earth's surface (Figure 2).

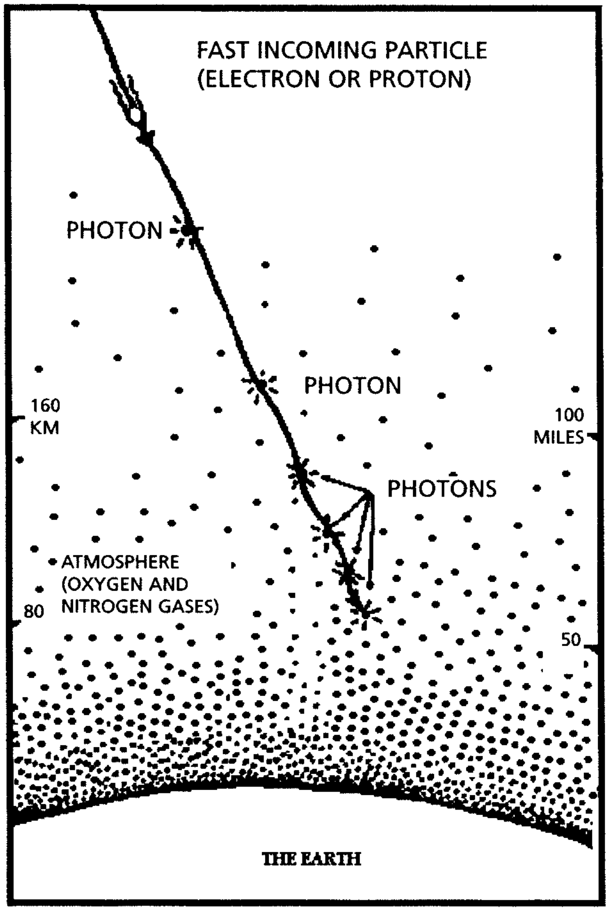

Figure 2.Fast incoming particles strike oxygen and nitrogen atoms high in the atmosphere, producing the colourful light (photons) we call aurora (Figure from Davis 1992).

The International Auroral Atlas, published in 1963, outlines a system for identifying, describing, and notating the many aurora forms, structures, and conditions. In *The Aurora Watcher's Handbook*, Davis describes three main types of aurora: 1) discrete, 2) pulsating and 3) hydrogen arc.

Discrete aurora have sharp boundaries, are the brightest, may be very colourful, and are the most common type in the early evening aurora. They may extend from 80 to several hundred km above ground. Discrete aurora come in the form of arcs, bands, draperies, and spirals. Arcs refer to aurora that extend from horizon to horizon with little uniform curvature, and bands have more irregular curvature. Segments of arcs and bands are called draperies because they resemble hanging curtains. Further curling may result in the development of a spiral. One must remember that in a matter of seconds the auroral display can change from one shape to another. Discrete aurora are further described by the extent of internal structure. Homogenous arcs and bands show minimal structure, for example folding. Rayed discrete aurora appear striated because the aurora curls up on itself in places and thus shines more brightly in those areas.

Pulsating aurora tend to be weak, less bright, often appearing colourless, and are often overlooked. These aurora are patchy in appearance and come and go in periods under 30 seconds. They are best spotted during the formation or break-up of discrete aurora. The third type of aurora is the diffuse aurora. In *The Aurora Watcher's Handbook*, the diffuse aurora is described as 'visually uninteresting.' They tend to occur in broad, uniform, east-west bands of light, similar in brightness and appearance to the Milky Way.

For those people interested in identifying and photographing these structures, many of the references listed in the text and at the back have good descriptions and photographs which greatly aid in understanding the various types. These references also describe special auroral conditions that may occasionally be encountered.

Man-made aurora?

Scientists are interested in the interaction between the solar wind and the magnetosphere because the electric field this interaction produces influences the convective motion of the charged particles throughout the magnetosphere. To track these movements scientists have launched rockets carrying cannisters of barium to altitudes of approximately 50 to 250 km above the earth's surface. At these altitudes, the cannister explodes releasing a cloud of barium particles into the space environment. The launch is made near dusk or dawn when the ground is dark, but the sunlight incident on the barium atoms cause the atoms to glow and allows scientists to track the drift of the aurora-like cloud.

Auroral noise?

Although no scientific evidence has been found, people in various parts of the world have reported hearing cracking or hissing sounds during auroral sightings. Today, few scientists believe that the sounds actually originate in the auroral region 100 km or more above the earth's surface. Further, no detector has ever detected sound in the audio range that can be attributed to auroras. Some scientists believe the experiments should be repeated using modern recording technology.

Viewing the aurora

The 'auroral oval' refers to a region surrounding the north and south geomagnetic poles that contain all auroral observations at one point in time (Figure 3). The oval, which is shaped like a frisbee with the centre circular area cut out, expands and contracts with increasing and decreasing input of energy from the solar wind (See websites in References). In general, there is a rather low chance of observing auroras over the poles. As one moves away from the North Pole towards lower latitudes the probability of observing auroras increases to a maximum around the border between the Northwest Territories and the rest of Canada. In Canada, aurora are best seen from the central Yukon, southeast through the Great Slave Lake area of the NWT, through northern Saskatchewan, Manitoba, and Ontario, and finally through central Quebec and Labrador. Moving further towards the equator the likelihood of observing auroras decreases. However, during large magnetic storms when a great deal of energy pours into the magnetosphere from the solar wind, aurora are sometimes seen at latitudes as low as Florida. In the NWT, tourists often visit Yellowknife and Fort Smith to view northern lights.

Theoretically, we should be able to see the aurora 24 hours a day, 365 days a year, but

Tips for Viewing the Aurora

Figure 3. The auroral oval. The bulge is on the night-side of earth, which is the side facing away from the sun. This is also the tail-side of the magnetosphere.

there are two factors that play a role in its visibility. First, the orientation of the sun's magnetic field in relation to the earth's magnetic field influences the amount of energy from the solar wind that can penetrate into the magnetosphere. The second consideration is sunlight. Because of the brightness of the sun, seeing the aurora is very difficult during the day.

Auroral displays are influenced by the solar cycle. Every eleven years, on average, the number of coronal mass ejections, which are huge bubbles of gas expelled by the sun into space, reach a maximum. Shortly after the maximum, that is early on in the declining phase, strong magnetic storms become more frequent. These storms generate aurora that are more dynamic than usual and occur closer to the equator. Simultaneously the polar cap – the region in the centre of the oval where aurora are not present – expands southward. For example, the auroral oval might push as far southward as the southern United States, with the polar cap as far south as Edmonton or Calgary. During these storms, the aurora are not visible in the NWT. After the storm, however, the polar cap shrinks and the aurora return to our area with a vengeance. At these times, the auroral displays can be spectacular.

On a shorter scale, aurora tend to show a 27 day cycle, corresponding to the 27 days it takes the sun to make one rotation. If an observer witnesses a vivid aurora they should check again 27 days later and may be lucky enough to witness another dramatic display.

Do other planets have aurora?

In our solar system, only three other planets are known to have aurora: Jupiter, Saturn, and Uranus. These planets have aurora because, like Earth, they possess magnetic fields and sufficient solar wind particle density. The other planets in our solar system lack either the magnetic field or a sufficiently strong solar wind.

Do people study the aurora?

Yes, researchers at a great number of universities, colleges, institutes and government agencies across the world are studying the aurora. Beginning in the 20th century people have applied science to the study of aurora. Understanding how the aurora develops and changes is important to the understanding of the solar system and outer space. On a practical level, the physical processes that create the aurora can disrupt radio wave propagation and thereby cause radio communication and navigation difficulties. Solar cells and surface coatings on satellites can be damaged by aurora, and the geomagnetic disturbances associated with aurora may cause power outages and fluctuations. For example, through the 1980s Hydro Quebec had several transformers damaged and power outages during magnetic storms. [These magnetic disturbances are also of interest to scientists studying cosmic rays, which in this case are particles from outer space that enter the earth's atmosphere. For more information refer to Houseman and Fehr (1996)].

Numerous space missions have also collected data on the aurora, and have looked at the aurora from a new vantage – from above.

Photographing the aurora

Photographing the aurora may be easier said than done. In order to photograph the aurora, one needs great patience, cold tolerance, a good camera, and great luck. One can try with the simple automatic camera, however, the results will probably be poor because of the quick shutter speed. Ideally, photographers should use a camera with a manual shutter and a 24 to 50 mm focal length lens with a maximum aperture opening between 1.2 to 2.8. A tripod and cable release are also useful. Regarding film, most photographers seem pleased with the performance of 200 to 800 ASA colour film. Davis (1992) recommends exposure settings between one and twenty seconds.

One must be prepared for very cold conditions when photographing the aurora in the North, therefore dress warmly and have either a warm shelter or vehicle nearby. It is also important to keep the camera as warm as possible because camera batteries can freeze within fifteen to twenty minutes in cold weather. Even if the camera is not fully automated, other parts, such as the shutter, curtain, and aperture blades can freeze. If the camera does freeze, place it in a plastic zip-lock bag and take indoors. As the bag and camera warm up the condensation will form on the outside of the bag and not in your camera! The only other item required is the aurora!

Summary

The aurora borealis, or northern lights, are one of the most fascinating aspects of the Canadian north and the circumpolar world. Many legends and tales have been passed down through the generations to explain the source and meaning of the aurora. Through these stories, we gain a greater appreciation of what the people of these lands thought and valued in their daily lives. From scientific studies, we are beginning to unravel the complex interactions between the sun and earth that yield the aurora. We now understand that protons from the solar winds flowing from the sun penetrate the earth's magnetosphere providing the energy for the electrons that ultimately collide with the atoms and molecules of the upper atmosphere to produce the auroras. As we move forward into the twenty-first century, scientists and the curious observers will be drawn to continue the study of this amazing natural phenomenon we call the aurora.

Acknowledgements

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Frequently asked questions about the aurora:
http://www.athena.ivv.nasa.gov/curric/space/aurora/aurofaq3.html

For photography tips:
http://www2.polarnet.com/~hutch/aurora.html

Information on the sun-earth system and space weather:
http://www.windows.umich.edu:80/spaceweather/

Information on the aurora oval's position and strength:
http://www.space.ualberta.ca/canopus.html

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